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A REVIEW OF CARBON MONOXIDE EMISSIONS FROM MOTOR VEHICLES DURING COLD TEMPERATURE OPERATION

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I. INTRODUCTION

In the past several years it has become increasingly apparent that air pollution emissions from motor vehicles in cold weather are different from those in warm weather. In particular, the starting of an engine which is cold, results in large emissions of unburned hydrocarbons and carbon monoxide. These emissions are called cold start emissions. It is these cold start emissions that I will discuss.

First I will present an overview of some of the important work that has been done in the area of cold start emissions. Next will be a discussion of the methods available for estimating emissions. The third topic will include a discussion of methods used for reducing cold start emissions. My fourth topic will include a presentation of some problems associated with cold weather operation. I will close with some discussion of the importance of cold start emissions in the overall scheme of planning to reduce automobile emissions.

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II. LITERATURE REVIEW

During cold temperatures the vaporization of fuel in automobiles becomes difficult, resulting in rich mixtures of fuel in air going into the engine. Until the engine reaches a normal operating temperature, combustion is inefficient and large amounts of carbon monoxide and hydrocarbons are emitted. Until the normal engine operating temperature is reached, the car is in a cold start mode.

In 1974 Polak reported the results of cold weather emissions tests on seven vehicles which were chosen to represent a typical Canadian fleet (14). The vehicles were tested over a 23-minute driving cycle which included a cold start. Temperatures from -10 to 80°F were used. From the results Polak presented the curves shown in figure 1. These graphs indicate, for example, that the carbon monoxide emissions at 0°F would be 151% of the emissions of 60°F.

Polak reported another series of tests which showed the effect of coolant heaters on emissions. As shown in Figure 2 the use of engine coolant heaters reduced hydrocarbon, carbon monoxide, and nitrogen oxides emissions substantially.

Miles and Homfeld presented some data in 1974 which described the effect of temperature on carbon monoxide hydrocarbon and nitrogen oxides emissions (11). The data is from 1970-71 model cars.

They made the following conclusions:

1. Hydrocarbons and carbon monoxide increase significantly as ambient temperatures are lowered.

2. The increase in hydrocarbons and carbon monoxide emissions at low ambient temperatures is less from cars equipped with catalytic converters than those not equipped with catalytic converters. Converters decreased the effect of temperature by a factor of at least three.

3. Nitrogen oxides emissions were unaffected by ambient temperature except when the vehicle's temperature override was used in conjunction with the exhaust gas recirculation valve.

During the winter of 1972-73, Environment Canada combined their efforts with those of the Alberta Motor Association to carry out an emission testing program to assess the influence of cold ambient temperatures on idle emissions (18). They reported that it was not possible to isolate any apparent effect of ambient temperature upon idle emissions because of fluctuation of "states of tune" and warmup times with the seven vehicles used.

Robertson summarized in 1973 the results of some studies performed by General Motors and by the Department of the Environment in Canada (15). He included references to work reported by Miles and Homfeld, and Polak. He discussed the time variation of temperatures of the carburetor snorkel air, carburetor fuel bowl, oil viscosity, automatic transmission fluid, engine coolant and rear axle.

In 1976 Shulz and Dale summarized a series of tests in which they used a 1971 Volvo with standard electronic fuel injection. They reached the following conclusions:

1. For the first 5 minutes of operation the emissions of the engine at -7°C were greater than emissions at 23°C; carbon monoxide emissions were 14 times higher, and hydrocarbon emissions were 10 times higher.

2. Nitric oxide emissions were relatively insensitive to differences in ambient temperatures during cold starts.

3. After the first five minutes the hydrocarbon, carbon monoxide and nitric oxide emission rates were not found to be a function of ambient temperature.

In 1973 Coutts et. al., reported on the first of a series of studies concerning carbon monoxide emissions in Fairbanks, Alaska (1). The report served to document the emission level of over 600 vehicles in the Fairbanks area for the warm idle mode. The report concluded that in the warm idle mode, cold ambient temperatures have a minimal effort upon vehicle emissions.

In 1975 Leonard completed a study in Fairbanks which concerned cold start automotive emissions (8). He tested over 100 vehicles from model year 1962 to 1975. Vehicles were not tuned before testing. Although specific correlations were not developed to relate emission rates to temperature, cold soak time or other variables, several important conclusions were drawn from this work:

1. Preheating an engine prior to startup can be effective in reducing emissions.

2. For temperatures below 0°F, a cold soak of only three hours can result in high cold start carbon monoxide emissions.

3. Pollution control devices being used are not effective in lowering cold start carbon monoxide emissions. Control devices in this study included catalytic converters and an air bleed to intake manifold.

4. Reducing engine size is the most effective way to reduce cold start carbon monoxide emissions, but temperature and cold soak time are major considerations also.

During the winter of 1977-1978 Leonard et. al., performed a series of tests to evaluate the effectiveness of four types of engine preheaters in reducing cold start carbon monoxide emissions (10).

Leonard concluded that engine preheaters can be effective devices for minimizing carbon monoxide emissions due to cold starts. Another device tested was an engine automatic starting device, which starts the engine whenever the engine temperature drops to a specific temperature. The engine is then automatically stopped when the temperature exceeds another setpoint. Figure 3 summarizes the average reductions Leonard reported in ambient temperatures ranging from 0 to -18°C.

In late 1977, G.R. Service of EPA reported results from testing five vehicles for cold start emissions (17). The purpose of the study was to generate preliminary data which would help to define the relationship between soak time, temperature, alternate driving cycles and automobiles emissions.

In an effort to break down the emissions into smaller increments Service collected seven sample bags of emissions over the 1975 Federal Test Procedure driving cycle. Part of his conclusions included the following:

1. At soak temperatures from 10-25°F, cold start emissions for the 1976 cars tested were 3 to 7 times higher than the emissions at 68-80°F.

2. The type of emission control system had a strong effect on both the level of carbon monoxide emitted and the distribution of carbon monoxide over the driving cycle.

3. Emission controls have not reduced carbon monoxide emission for actual low temperature cold starts as much as for the normal federal test procedure temperature start conditions.

4. Only the cold start mode was significantly affected by temperature.

5. Because cold soak time is strongly temperature dependent, in very cold weather a vehicle can have multiple cold starts in an 8 hour period if soak times are two hours or more.

6. Temperature and cold soak time effects on hydrocarbons were similar to those on carbon monoxide.

In 1978 Ostrouchov reported results obtained from extensive tests of cold weather emissions from 13 1974 and 1975 motor vehicles representing a wide variety of car types and emission technology (13).

1. A considerable increase in hydrocarbon and carbon monoxide emissions takes place as the ambient (test) temperature is lowered.

2. Emissions during the first phase of the 1975 Federal Test Cylce after a cold start account for nearly all CO emission increases observed at lower temperatures.

3. Emissions from a vehicle's warmed up running mode are not appreciably affected by ambient temperature.

4. The rate of change of CO emissions with temperature depends upon the emission control technology on the automobile being used.

Of particular note, Ostrouchov found considerable differences in the emissions between cars with different pollution control systems. Cars equipped with air injection had generally lower hydrocarbon and carbon monoxide emissions than cars without air injection. The Honda CVCC demonstrated the lowest hydrocarbon and CO emissions throughout the ambient temperature range tested.

In October 1978, Heinmiller of EPA reported the results of some tests made on randomly selected vehicles from Chicago (6). The vehicles tested were not tuned before testing. 84 vehicles were tested, each vehicle being tested twice at a low temperature and twice at a higher temperature. He made the following conclusions:

1. A vehicle with a cold engine produces significantly more hydrocarbons and carbon monoxide in a low temperature cold start test than does a vehicle under standard conditions.

2. The major contribution to the higher low-temperature emissions on the federal test procedure occurs during the cold transient phase.

3. Vehicle fleets from different manufacturers vary widely in low temperature performance.

In November of 1978, Hayden reported the results of some studies performed on 1976, 1977 and 1978 automobiles (6). The study used several types of cars and different fuels. Although the study was primarily directed towards fuel economy it did include a discussion of emissions of carbon monoxide, hydrocarbons and nitrogen oxides.

He found that conventionally carburetted engines had considerably higher emissions than lean burn stratified charge, turbocharged or diesel engines at colder temperatures. He concluded that the oxidation catalyst was not lighting off early enough to be effective in emissions reduction at colder temperatures. Figure 4 below displays the results which be obtained.

Emission tests have been made recently on 1978 automobiles and 1980 prototypes at different temperatures (7). Figure 5 below displays the results from emission testing of a 1978 Ford Pinto and a 1980 Ford Prototype. In both vehicles the emissions are considerably higher at lower temperatures than they are at higher temperatures. However the ratio of carbon monoxide emitted at the lower temperature to the carbon monoxide emitted at the higher temperature is higher for the 1980 Protoptye than for the 1978 model.

III. METHODS FOR ESTIMATING EMISSIONS

Each area which has been classified as nonattainment for any air pollutant under the United States Clean Air Act Amendments of 1977 is required to develop a plan to attain the standard. With regard to carbon monoxide, such plans will primarily emphasize transportation controls, because motor vehicles are the predominant emitter of this pollutant. In the plan, various alternatives for reducing carbon monoxide must be considered and justified.

The selected plan must provide reasonable assurance that attainment of the national ambient air quality standards will be achieved by 1982 if at all possible, but in any event no later than 1987. Therefore substantial technical analyses of transportation and air quality data are required in these plans. However, the data used in these analyses must be accurate. If it is not, then incorrect conclusions are likely to be reached. This can readily result in the selection of ineffective but expensive strategies for attaining the air quality standards.

One of the most important analyses to be made is the identification of the problem. For carbon monoxide this requires accurate (1) ambient air quality data, (2) traffic data and projections, and (3) vehicle emission rates. This report is concerned only with the vehicle emission data and how this data is analyzed.

EPA has developed several different procedures for measuring automobile emissions over the last decade. The current procedure is called the 1975 Federal Test Procedure. With this procedure the car is first allowed to stand for at least 12 hours at an average temperature of about 75°F before the engine is started. It is then started and driven in an established cycle of starts, stops, acceleration, deceleration and constant speeds.

During the driving cycle, a constant fraction of the exhaust flow is collected in one of three bags. Bag 1 represents the emissions from the transient cold start operation of the test, bag 2 represents the emissions from the stabilized operation phase, and bag 3 represents the emissions from the transient hot start operation.

Based on the procedure just described, many different vehicles have been tested and EPA has compiled emission factor tables for different model years (12). These tables contain procedures for calculating emissions for an "average" automobile of a given model year. The emissions are then averaged over the total miles traveled for the driving cycle. The computed average CO emission-per-vehicle-mile-travelled is then used for evaluating control strategies. The EPA emission estimation method includes a correction factor which reflects temperature effects.

Figure 6 shows the effect of ambient temperature and cold start conditions on the predicted average 1978 emission rate of a 1977 automobile run through the federal test procedure. Of interest is that the contribution of cold start emissions to total emissions increases substantially with lower ambient temperatures. For instance, cold start emissions at 0°F

make up 81% of total emissions, while they make up only 36% of total emissions at 75°F.

The method just described makes allowances for conditions which vary from the Federal Test Procedure. However, the emissions estimated from EPA emissions book may not be accurate estimates for cold regions, primarily because they are based on vehicle-miles-travelled.

In the case of actual cold weather driving situations, the cold start carbon monoxide emissions cannot be realistically simulated using the EPA method. Automobiles are often not driven until they are warmed up and thus vary significantly from the assumed federal driving cycle. Most cold start emissions in Fairbanks and Anchorage probably occur before cars are even driven.

Figure 7 shows a comparison of the EPA temperature correction factor with similar factors calculated from Ostrouchov's data and from Hayden's data.

Another problem with cold start emission estimations is that research reported in the current literature does not agree with the temperature effect upon emissions predicted by the EPA method. This is at least partially because EPA values for emissions are only valid above 0°F.

Of particular note is that the Federal method predicts temperature sensitivity to be almost an order of magnitude less than that found by Hayden. The Federal Method also predicts a lower temperature sensitivity than Ostrouchov's data for 1975 U.S. cars. If Hayden's data are correct then the EPA emission factor book needs to be revised since the numbers obtained would not be representative of emissions from newer cars.

A method needs to be devised for assessing actual cold start emissions separately from the driving cycle. Also, the EPA method is only valid above 0°F, and data is needed to determine quantitatively, the automobile emission factors from 0°F to about -15°F. Automobiles are not started very well without preheated engines below about -15°F so data would not be useful below that point.

Although a good quantitative method for determining emissions during cold conditions is not generally available, there have been data presented which can assist in developing control strategies. Figure 8 below contains a comparison of the results.

Some discussion is appropriate about the results in Figure 8. First, note the variability of total emissions from one method to another.

Even though the total emissions vary widely from method to method, the percent of the total emissions which is due to cold start is consistently high. Such a high percentage suggests that even if the Federal Motor Vehicle Emission Control Program could eliminate all warm vehicle operation emissions, the total vehicle emissions would not be appreciably changed.

The Clean Air Act requires a 90 percent reduction in CO emissions from these emissions found from 1970 model year vehicles. However, EPA is only requiring the 90% reduction at 75°F. More recently EPA has attempted to apply the 90 percent reduction requirement to mean 90% of emissions for different temperatures. Specific emission limitations for three temperatures have been proposed as shown in figure 9.

To date the proposed guidelines have not been promulgated.

Earlier I presented data which indicates that although the basic emission rate at 75°F has been decreasing in the last few years, the emission rate at lower temperatures may have been increasing substantially. If that is true then it is imperative that emission guidelines and/or requirements be developed for lower temperatures. Otherwise, there will be no incentives to encourage reduction of low temperature carbon monoxide emissions.

There appear to be three basic methods for substantially reducing cold start emissions. They are:

1. Advanced emission control technology, in particular the use of exhaust manifold air injection.

2. Engine preheat devices, including electrical plug-ins, automatic exhaust manifold air injection.

3. Alternate engine technology which has inherently low cold start emission characteristics, such as the Honda CVCC (compound vortex controlled combustion) engine.

Ostrouchov (13) presented data which compares the emissions of vehicles with different pollution control devices. The cars which meet the California standards used manifold air injection, exhaust gas recirculation and an oxidizing catalytic converter. The lower emissions of the California group of cars was explained as being due mostly to the air injection. Figure 10 below displays the percent reduction of carbon monoxide emissions of the California automobile group over the Federal standards group of cars that Ostrouchov used.

Air injection is accomplished by pumping air into the exhaust port of each cylinder. The extra air oxidizes unburned hydrocarbons and carbon monoxide into carbon dioxide and water. During the cold start phase of operation, excess hydrocarbons and carbon monoxide are present under rich choke conditions and the additional air is needed to better oxidize the incompletely burned gases.

Preheat Devices

The second basic method for reducing cold start emissions is through the use of preheat devices. Work by both Leonard and Polak indicates that potential reductions from 44% to 86% are possible depending upon the device used and the degree of preheat employed.

Frost Plug

Two main types of preheaters are in common use today. One type, called the frost plug, is an immersion type electrical heater which is installed in one of the engine block freeze plugs. The frost plugs, being located in the lower part of the water jacket, readily cause a convection pattern to be established as the warmer water rises to the top of the block.

Circulating Heater

Probably the most commonly used preheater is the circulating heater. The circulating heater is a device which is external to the engine, being connected by hoses to the top and bottom of the engine. The electrically heated element causes the warm water to rise through the hoses to the top of the engine block. Cool water is drawn from the bottom of the block by a termal siphon as warm water goes to the top of the block.

Thermosaver

Another device has been partially developed which stores waste heat while the engine is running. (13) The heat can then be released when the operator desires to warm the engine. The heat storage takes place by using a chemical which changes phase from crystalline solid to a liquid, and then back to the solid state after releasing its latent heat of crystallization. The technology of this type of heater needs to be refined before it becomes a viable tool for mitigating cold start emissions. Even though it is not a fully developed method, it should be explored because of its dual potential for saving energy, and reducing cold start emissions.

Auto-Start

A final method of reducing emissions by preheating the engine is the automatic engine starting device. The engine is automatically started whenever the engine temperature gets below a setpoint. The engine continues to run until an upper setpoint temperature is reached. The engine therefore never gets cold enough to have a cold weather cold start. An intermittant emission would be expected from this device, however. Preliminary tests suggest that the total emissions for using the auto start device are substantially lower than if the car is started from a cold soak condition (10). However, more work is needed to fully characterize the emission reduction potential of this device.

Alternative Engine Technology

Honda CVCC Engine

The potential solutions to cold start automotive emissions discussed thus far have involved add-on devices to the basic automobile engine. However the ultimate solution may rest with innovative design of a different engine. For example, the Honda Motor company has recently mass produced an engine which is showing promise in both fuel economy and low pollutant emissions without external devices.

The CVCC (Compound Vortex Controlled Combustion) stratified charge engine has been tested by both Ostrouchov (13) and Service (17). The engine has two combustion chambers in each cylinder. On intake a rich fuel-air mixture enters the pre-chamber while a lean mixture enters the main chamber. Under compression a moderate fuel/air mixture forms near the opening between the main chamber and pre-chamber. The spark plug ignites the rich mixture which then ignites the moderate mixture, then the lean mixture. This sequence leads to a stable slow burn which drives the piston down.

Figure 11 below displays Ostrouchov's data for the CO emissions from the Honda. Also shown for comparison are the emissions from cars meeting the 1975 Federal emission standards and from cars meeting the California standards. At low ambient temperatures, the Honda emits from one fourth to one third of the CO that the 1975 Federal standards cars emit. The Honda also emits from 80 to 90 percent of the CO that California group emits. The smaller displacement Honda engine would be expected to emit less CO than the California group cars tested, so the overall emissions may not be significantly different for similar sized engines.

However, the Honda CVCC engine accomplishes the low emission rate without use of conventional emission control devices such as the catalytic converter. Also, the low emissions are accomplished with a high fuel economy.

Innovative designs such as the CVCC engine should be strongly encouraged for emission control.

Diesel Engine

The diesel engine is an alternative engine which has the lowest carbon monoxide emissions for any car. Hayden's report included results from two automobiles with diesel engines. The diesel engines emitted very little carbon monoxide: Even at temperatures as low as -10°F the emissions were less than 2 gm/mile. The EPA Emission Book, AP-42, estimates that carbon monoxide output from light duty diesel engines are 1.7 gm/mile. The diesel engine then represents technology which is available and emits low amounts of carbon monoxide even at cold temperatures. Such technology should be encouraged for emission control.

Other engine technologies discussed in Chapter IV, includng a lean burn carburetor and a turbocharged spark ignition engine with a knock limiting sensor, should be considered in future evaluations.

V COLD WEATHER OPERATIONAL PROBLEMS AND EMISSION CONTROLS

As may be expected, cold weather operation of motor vehicles presents specialized problems. Some of these problems are basic: Left outside in -30°F weather, a car simply will not start without some preheating; rubberized components lose their elasticity or deteriorate quickly. Perhaps the greatest problem affecting pollutant emissions is in the carburetion system. Manual chokes are often used excessively, automatic chokes sometimes do not work and usually are set for driveability rather than low emissions.

Operation and maintenance of the vehicle, therefore, are probably at least as important as the vehicle emission control design for controlling pollutant emissions. Cold weather driving problems which have major effects on air pollutant emissions are caused by carburetor chokes, lean misfire, exhaust gas recirculation valves, spark plugs, synthetic rubber compounds, condensation, and lubricants. Each of these is discussed below.

Chokes

Although not specifically a pollution control component, choke systems are the dominant factor in cold starts. While chokes would be effective in lessening the cold start problem, they are subject to improper use by the operator.

The automatic choke is a compromise. Its biggest disadvantage is that it cannot be set to respond to the widely varying range of temperatures experienced. To be most efficient, it should be reset a number of times during the course of the winter. Even setting it presents difficulty because it should be set at ambient temperature. Thus, the auto must be cold soaked, and few mechanics will make the necessary adjustment outside in ambient air.

Some car models are equipped with "quick-release" chokes which are designed to lower CO emissions during the cold start. The engine will thus continue to warm up at a lower CO level, but would probably stall if engaged in gear. Consequently, there is little incentive to have a choke set for low emissions when start-ability, faster start up, and the ability to pull away sooner is denied.

Lean Misfire

Lean misfire occurs because of a lack of adequate fuel vaporization. It can be cured by a number of ways, some of which increase rather than decrease air pollutant emissions. The most common cure is adjustment of the carburetor to a richer fuel mixture (lower air to fuel ratio, causing increased CO emissions. Other methods for reducing lean misfire might include insulation of the intake manifold, heating of the manifold, or more efficient means of atomizing the fuel as it is introduced into the manifold. Lean misfire is most often associated with the front cylinders and in-line engines.

Another problem is that carburetor adjustment specifications are primarily set to warm weather conditions, such that tradeoffs between driveability and emission levels are optimized. However, this does not appear to have been done for cold weather conditions. Cold weather engine tuneup adjustments are accomplished primarily to improve engine performance characteristics, and thus minimize lean misfire. This also increases CO emissions, but does make the car driveable.

Concern has been expressed by auto dealers in Fairbanks about future car models, many of which will likely have sealed carburetors which cannot be adjusted to cold weather conditions. This factor should be evaluated by auto manufacturers, and serious consideration should be given to developing a cold-weather carburetor so that driveability and emission control are optimized.

EGR

EGR (exhaust gas recirculation) valves become susceptible to two problems. First, the passageway valve seats and valves can become plugged with carbon caused from prolonged choking and/or enriched idle, or from excess amounts of lead. Also, the EGR diaphragms (some have dual diaphragms) are made of synthetics and thus are susceptible to cracking. Driveability problems are sometimes experienced as idles are commonly set higher in the winter, primarily because charging systems are under a heavier load in the winter because of lights or more often, heaters, defrosters, etc. Hence the EGR valve coil sometimes opens at the higher idle, causing stumbling when the car is set in motion.

Spark Plugs

A well recognized problem, wide-gap plugs do not fire consistently. Also, stock plugs are often too cold. In either case it's a simple matter of replacement. Plugs can also become fouled with carbon from excessively rich A/F ratios such as occurs with excessive choking, and from lead buildup.

Synthetic

Hoses, diaphragms and insulation made of synthetic rubbers are susceptible to rapid deterioration. The rapid deterioration is primarily due to the exposure of the material to rapidly changing temperatures from extremely cold to hot. Such exposure results in large thermal stresses. Eventually vacuum systems will not function effectively as the hoses deteriorate. The same is true for diaphragms in the EGR valve, fuel pump, and vacuum advance systems. Wire insulation expands and contracts dissimilarly from the metal, causing cracking wire and possible electrical shorting problems.

The trend towards lighter weight vehicles for fuel economy reasons will further increase the use of synthetic compounds.

Condensation

Condensation from blow-by gases in the valve cover is virtually unavoidable. Condensate freezes and plugs PCV hoses, and other vacuum hoses such as passages from choke to carburetor. This usually is a temporary condition since the frozen water vapor tends to melt when the engine warms up.

Other Solutions

Cold start effects can be minimized not only by preheating, but also by keeping heat in the engine and engine compartment. This can be done through the use of something as simple as a blanket on the hood, to insulating the underside of the hood, or insulating the outside of the oil plan to keep the oil warmer.

In some cases, fan blades can be shortened or removed to prevent cold air from being blown needlessly on the engine. An engine that is started after a short cold soak is usually still warm, but its temperature will drop right after start-up due to cold air blown on it. Most autos with air conditioning have a temperature controlled fan blade that regulates the use of the fan, which will tend to minimize this effect.

Summary

While emission control devices, engine maintenance specifications, and compliance with emission control regulations are generally established according to warm weather operation, it is clear that cold weather driving necessitates deviations from common approaches. A more effective and reliable automatic choke, and more optimum timing/carbureator settings are needed to minimize cold weather air pollutant emissions. In addition, anything that can be done to ensure more efficient and quicker fuel vaporization - especially at cold temperatures - is encouraged.

VI CONCLUDING REMARKS

The United States Clean Air Act Amendments require U.S. cities to designate areas which exceed the criteria pollutant standards as non-attainment areas. The states must then provide that the standard will be met by 1987, at the latest.

In the case of pollutants which are primarily automobile related, transportation control strategies must be developed which will result in attainment of the standards.

The transportation control strategies which are appropriate for many areas of the country may have no noticeable effect upon pollutant concentrations in areas of the country in which cold starts are prevalent. In areas of extreme cold, cold starts may account for most of the carbon monoxide. As an example, in Fairbanks, Alaska as much as 90% of all carbon monoxide is estimated to come from cold starts. In fact, several areas of the United States experience wintertime carbon monoxide concentrations in excess of standard. Such occurences suggest that the cold start problem is probably more pervasive than has been commonly assumed. Figure 12 contains a partial listing of some selected cities in which the carbon monoxide standard is exceeded in wintertime.

It is important for any agency to be able to determine the extent of the cold start problem before it establishes transportation control strategies. Otherwise the transportation control strategy will end up solving a problem which does not exist at the expense of not solving a problem which does exist.

I have already suggested that the United States Federal Motor Vehicle Emission Control Program, which does not include specific limitations as a function of temperature might lead to a reduction of warm weather emissions but not appreciably affect overall emissions because of its failure to accurately address cold starts.

The overall problem of cold starts has not yet been adequately defined quantitatively. As I have mentioned, several items need to be more fully researched. Such research should include the items shown on Figure 13. I will conclude my presentation by reviewing some of the most important items of research that need to be examined in order that strategies for reducing automobile pollutants can be more realistically evaluated than is now possible.

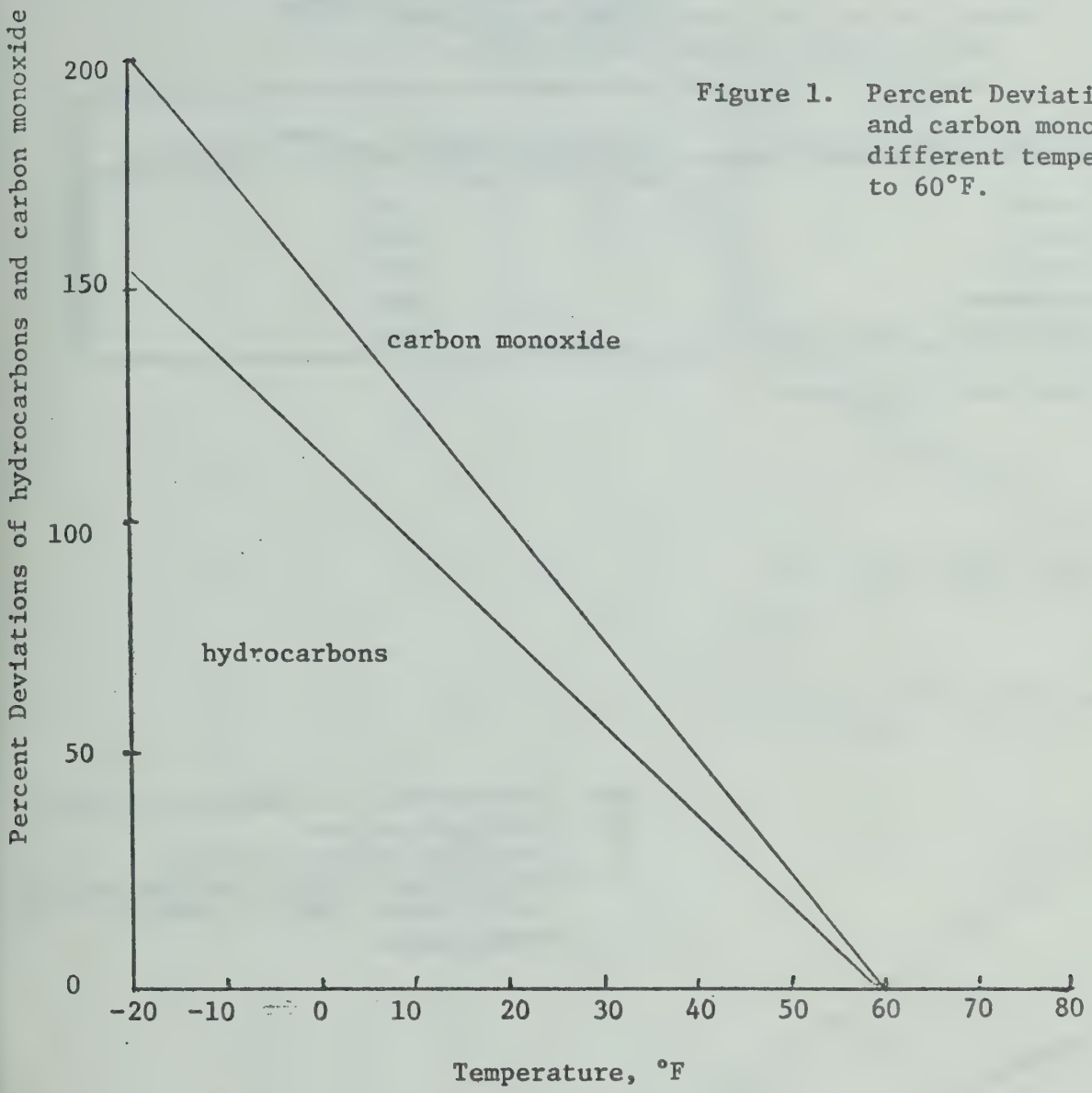

Figure 1. Percent Deviations of hydrocarbon and carbon monoxide emissions at different temperatures compared to 60°F.

Figure 2. Effect of Engine Coolant Heaters on Engine Emissions (14).

Pollutant	Emission rate (gm/mile at 0°F) without heater	with heater	% decrease
Hydrocarbon -car 1	5.3	2.6	51
car 2	4.1	3.2	22
Carbon Monoxide-car 1	122	68	44
car 2	51	32	37
Nitrogen Oxides-car 1	2.8	2.4	32
car 2	1.9	1.5	38

Figure 3. Reduction in Cold Start Carbon Monoxide* Due to Use of Preheat Devices (10).

Cold Start with Preheat for	Estimated Cold Start CO Reduction
0 hours	0%
1 hour	43%
2 hours	69%
Continuous	86%
Continuous – auto start	81%

*Data from Table IX, Leonard.

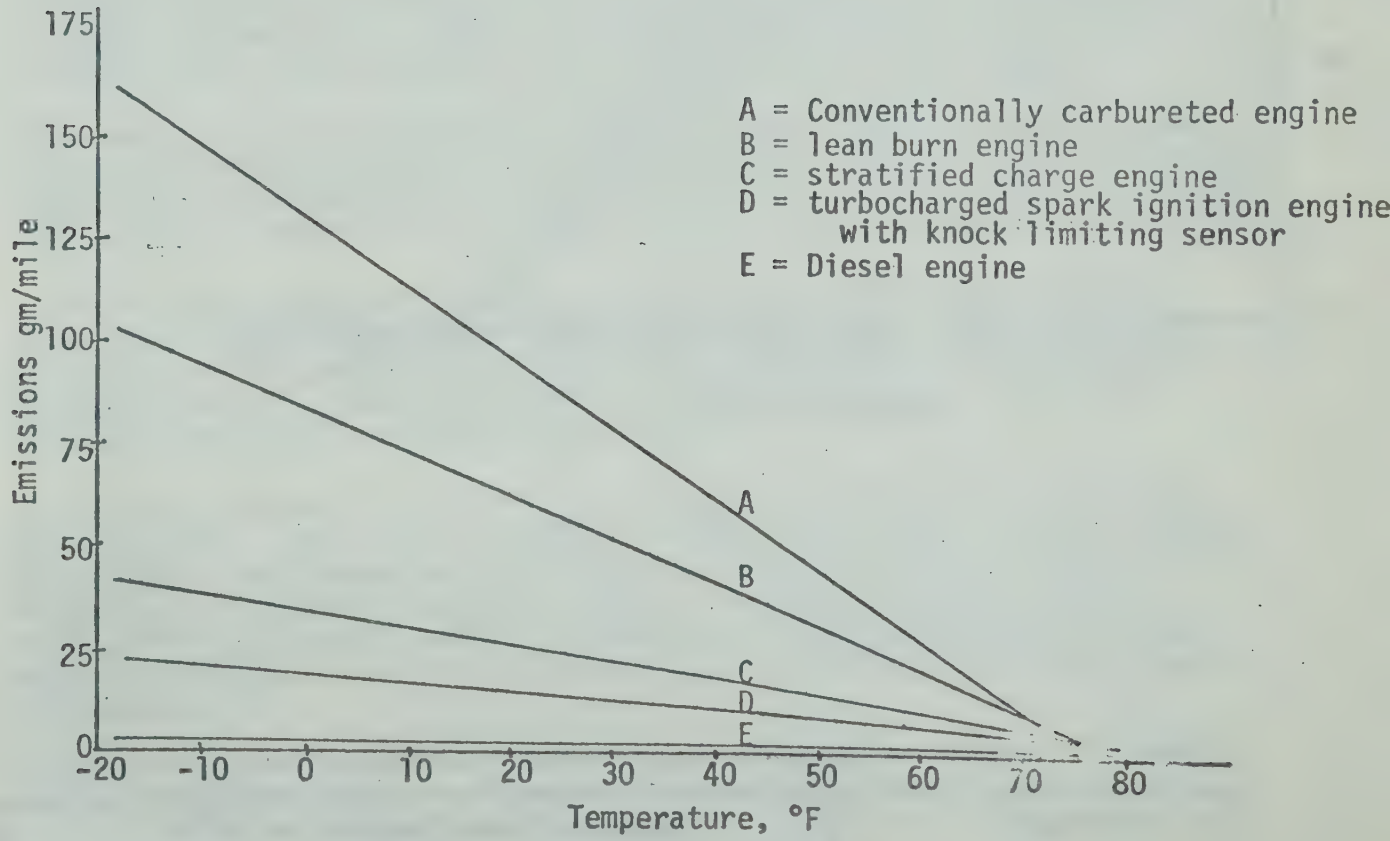

Figure 4. Emissions of Carbon Monoxide from five types of automobiles (5).

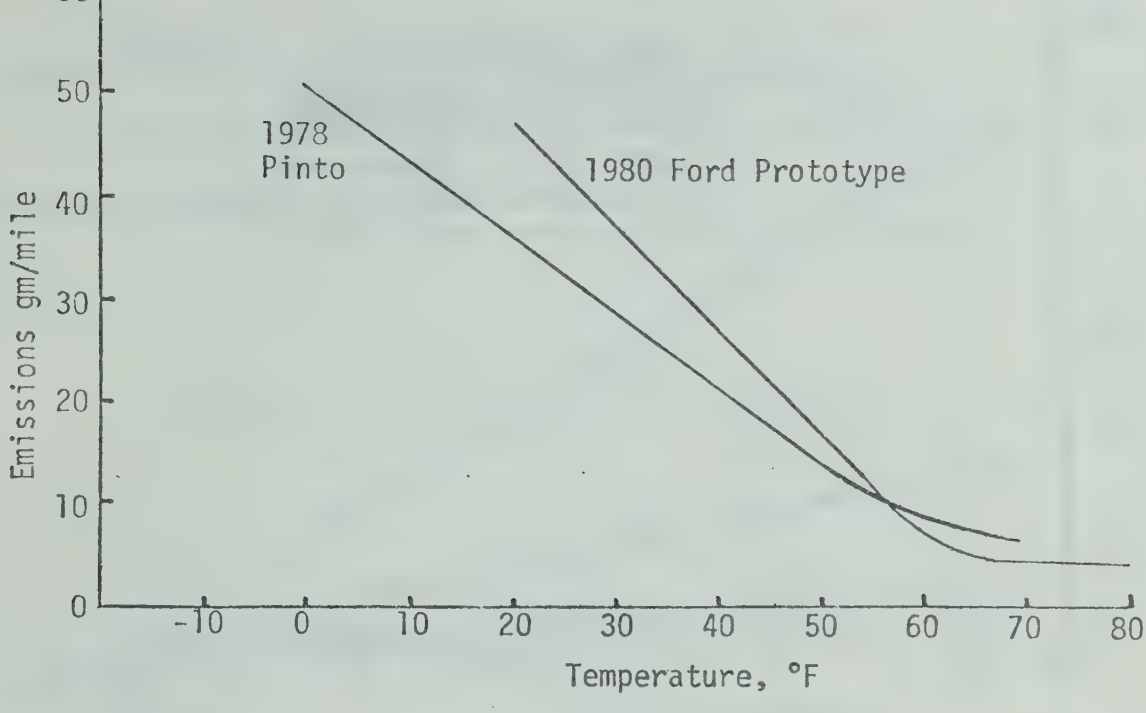

Figure 5. Emissions of Carbon Monoxide from a 1978 Ford Pinto and a 1980 Ford Prototype (7).

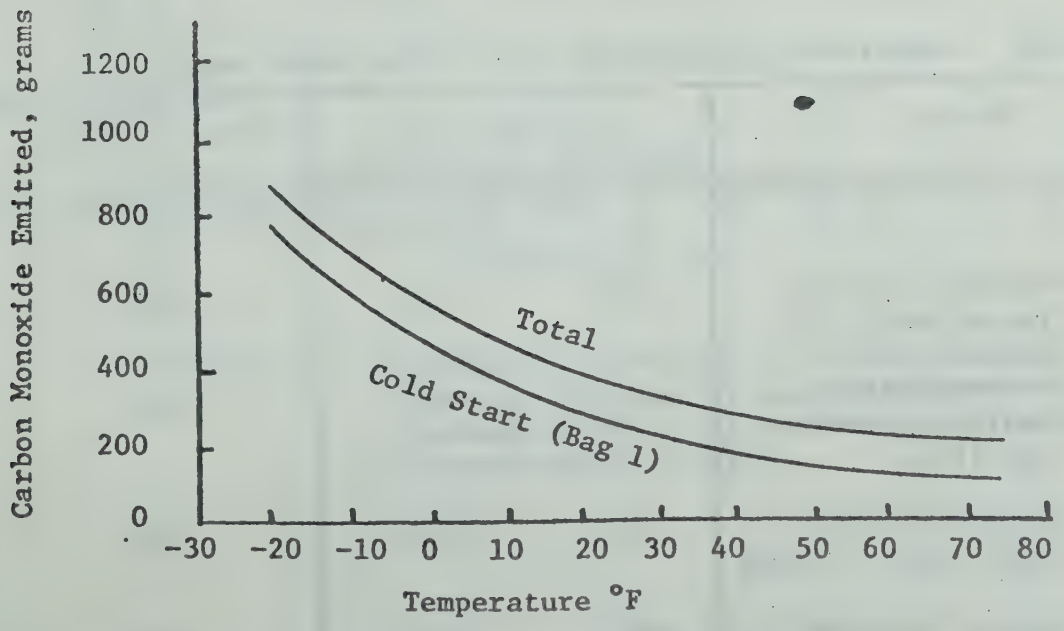

Figure 6. Effect of Ambient Temperature on emissions of carbon monoxide from a 1975 automobile in 1976 during one cycle of the Federal Test Procedure (12).

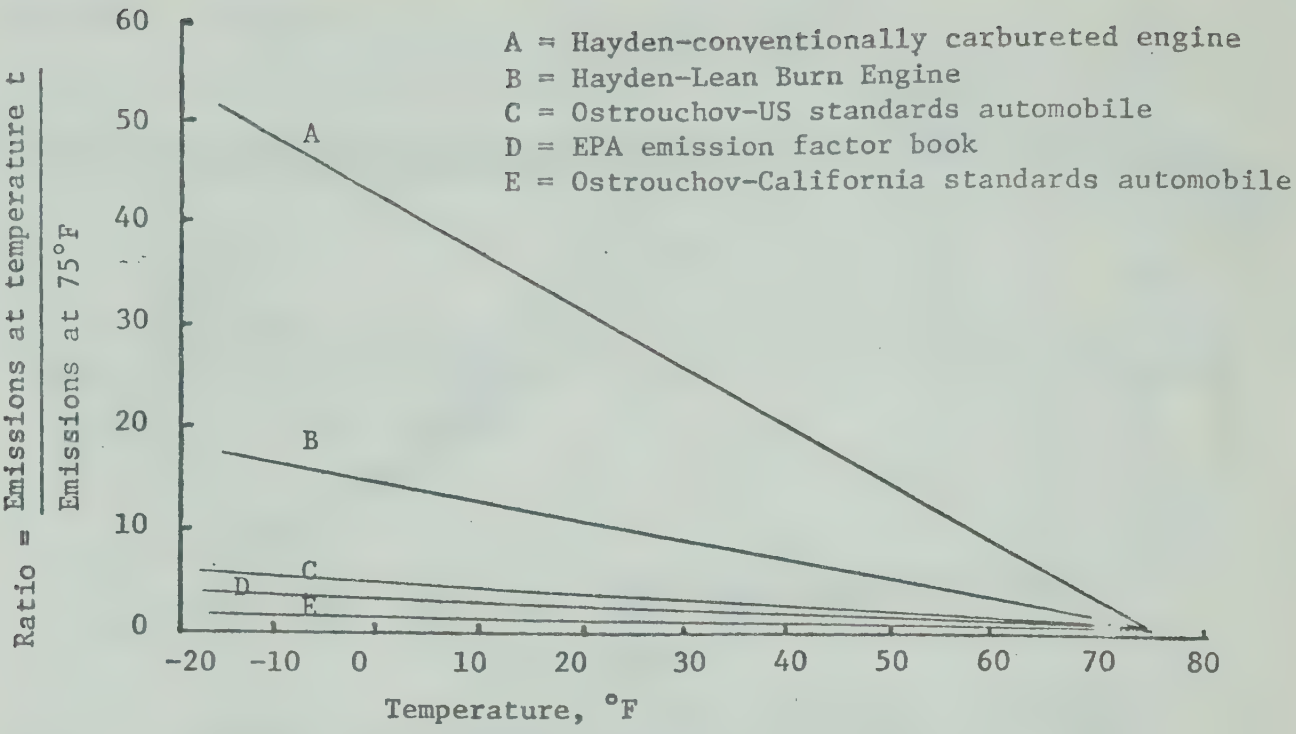

Figure 7. Effect of Temperature on emission factor ratio (5,12,13).

Figure 8. Comparison of emissions of CO using three methods

Method	Cold Start CO estimated contribution		Total emission of CO
	gm	% of total	gm
I. EPA-1978 emission factor book (12).	409	81%	505
II. Ostrouchov-1975 California model car (13).	111	91%	121
Ostrouchov-1975 U.S. model car (13)	321	85%	378
III. Miles & Homfeld* (11)	463	96%	480

*The 1972 test procedure was used to obtain those figures. Numbers have not been converted to be directly comparable to 1975 CVS-CH method.

Figure 9. Proposed emission guidelines (21)

(grams/vehicle mile)

Temperature, °F	1980	1981+
75	7.0	3.4
50	9.7	4.7
20	12.3	6.0

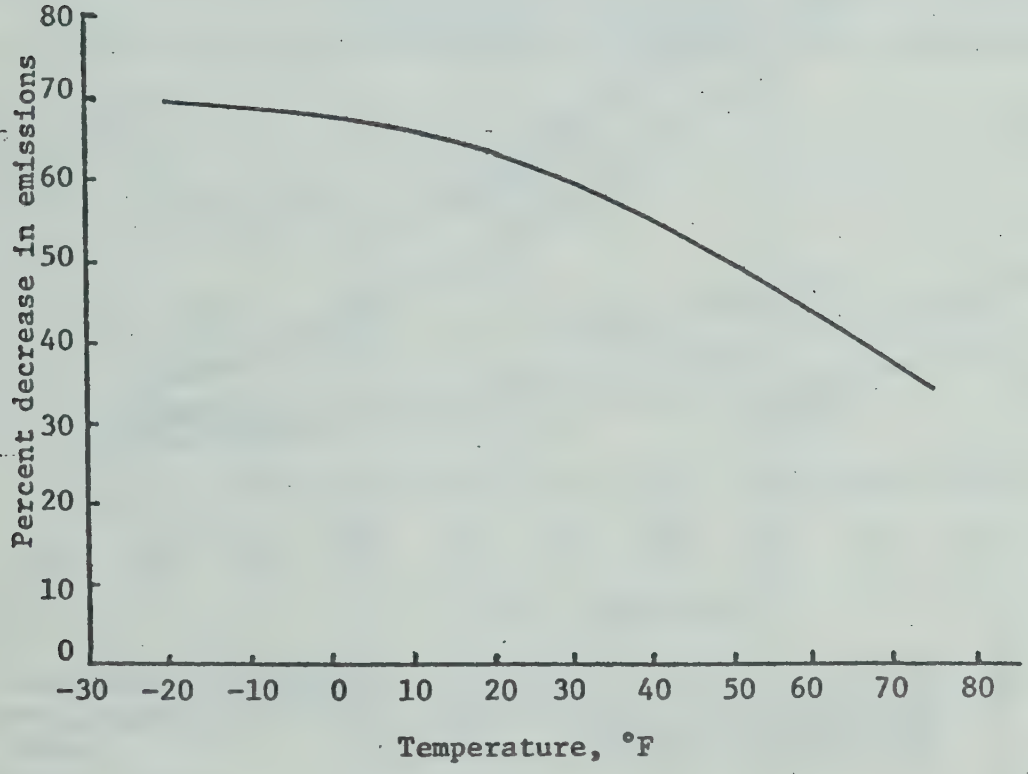

Figure 10. Decrease in emissions of carbon monoxide from cars equipped to meet California standards compared to cars equipped to meet national standards (13).

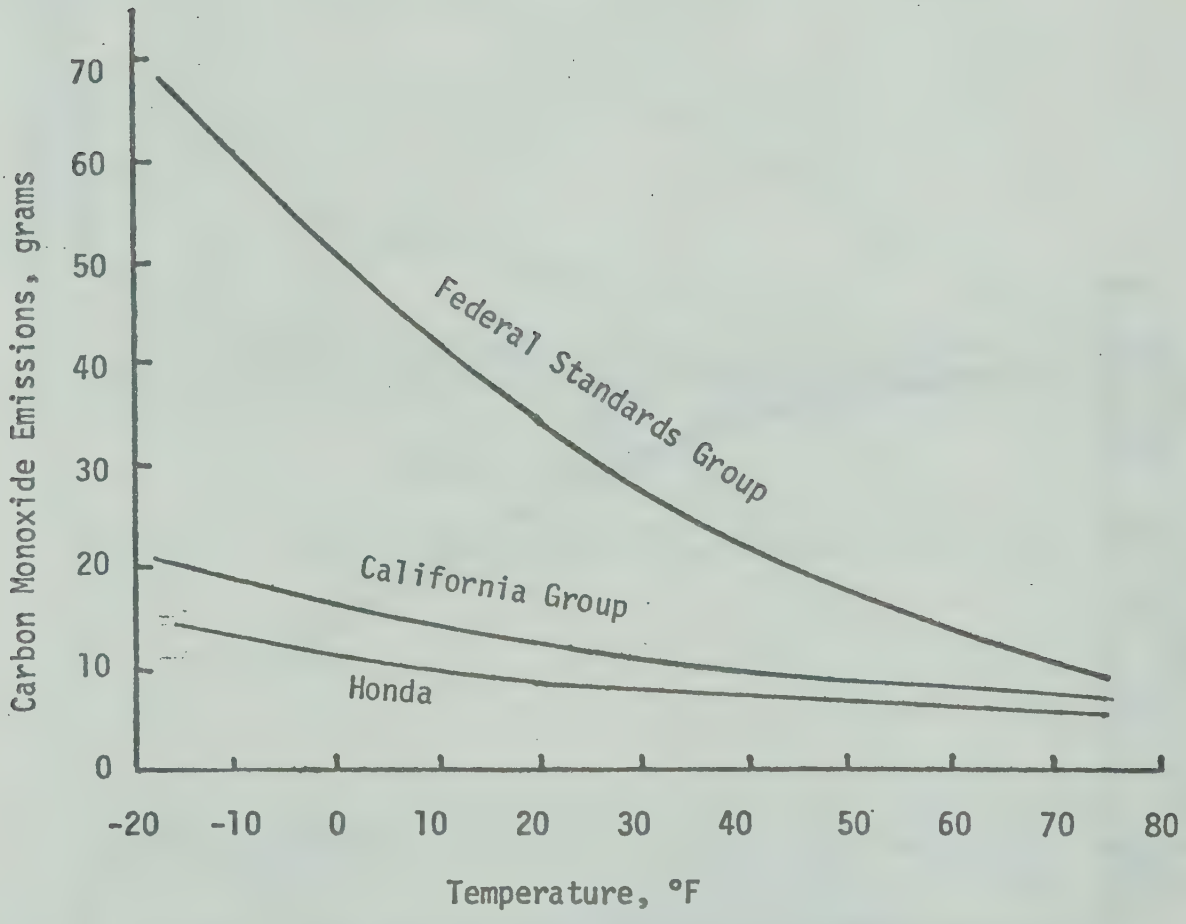

Figure 11. Emissions of carbon monoxide at low temperatures for the Honda CVCC compared to the Federal Standards and California Standards groups (13).

Figure 12.

PARTIAL LISTING OF
CITIES EXPERIENCING WINTERTIME CO CONCENTRATIONS
IN EXCESS OF AMBIENT AIR QUALITY STANDARDS

City	1-hr 40 ug/m^3 standard reached or exceeded	8-hr - 10 ug/m^3 standard exceeded
Fairbanks, Alaska	x	x
Denver, Colorado	x	x
Chicago, Illinois	x	x
Springfield, Massachusetts	x	x
Alburquerque, New Mexico	x	x
Cleveland, Ohio	x	x
Spokane, Washington	x	x
Seattle, Washington		x
St. Cloud, Minnesota		x
Boston, Massachusetts		x
Minneapolis, Minnesota		x
Tucson, Arizona		x
Phoenix, Arizona		x
Louisville, Kentucky		x
Cincinnati, Ohio		x
Portland, Oregon		x
Salt Lake City, Utah		x
Numerous cities in California		x
Las Vegas, Nevada		x
Reno, Nevada		x
Anchorage, Alaska		x
Boise, Idaho		x

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